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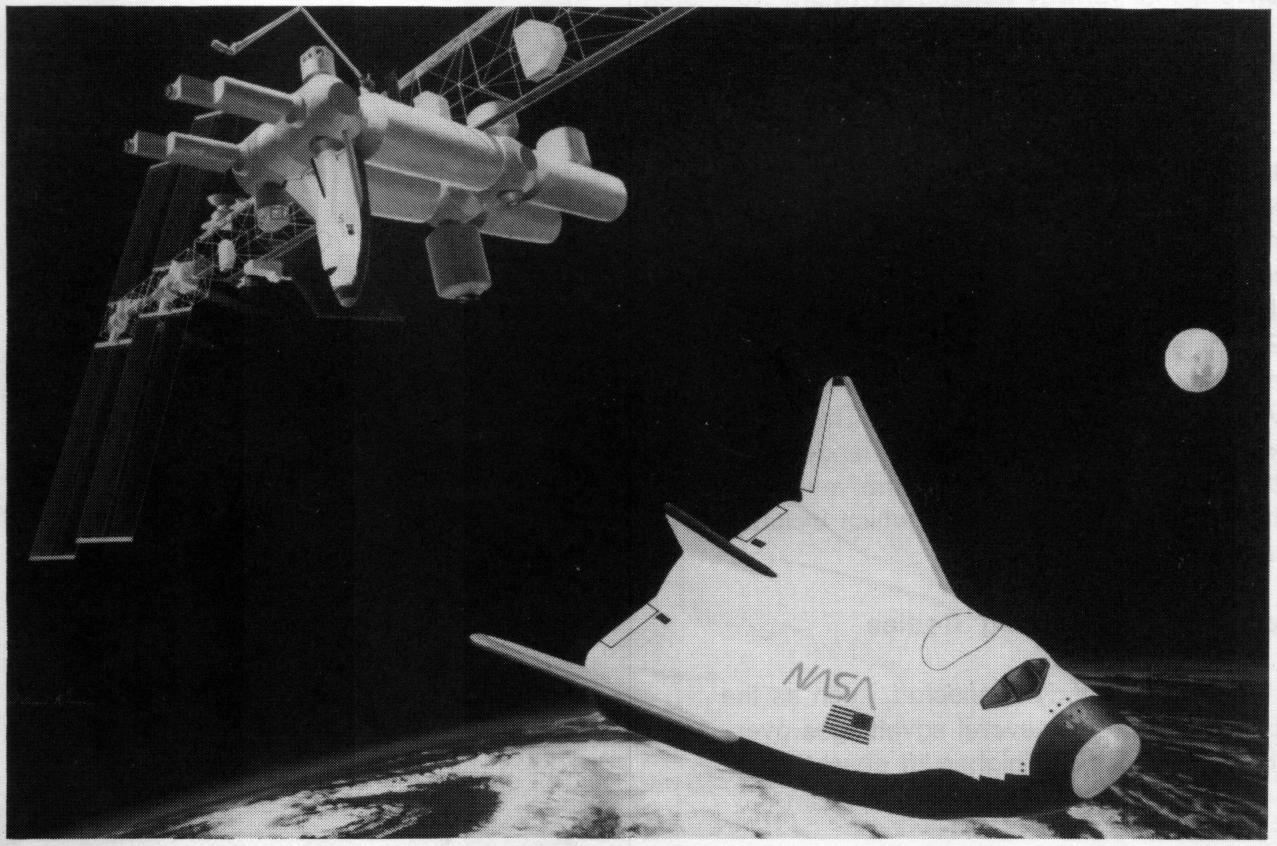
HL-20 MODEL FOR PERSONNEL LAUNCH SYSTEM RESEARCH

A Lifting-Body Concept

For the past several years, NASA's Langley Research Center in Hampton, Va., has been studying an enhanced lifting body candidate for manned orbital missions. This concept, designated the HL-20, has been designed for low operations cost, improved flight safety and conventional runway landings. With increasing national interest in obtaining routine access to space, a number of Earth-to-orbit transportation systems are being studied. One, referred to as a Personnel Launch System (PLS), could utilize the HL-20 and an expendable launch system to provide manned access complementing the Space Shuttle. A full-size engineering research model of the HL-20 was constructed by the students and faculty of North Carolina State University and North Carolina A&T University for studying crew seating arrangements, habitability, equipment layout and crew ingress and egress. This engineering research model is 29 feet long and provided the full-scale external and internal definition of the HL-20 for studies at the Langley Research Center.



NASA Langley HL-20 lifting body PLS

The PLS mission is to transport people and small amounts of cargo to and from low-Earth orbit, i.e., a small space taxi system. Although not presently approved for development, the PLS is being designed as a complement to today's Space Shuttle and is being considered an addition to the manned launch capability of the United States for three main reasons:

Assured manned access to space. In the era of Space Station Freedom and subsequent missions of the Space Exploration Initiative, it is imperative that the United States have an alternate means of getting people and valuable small cargo to low-Earth orbit and back should the Space Shuttle be unavailable.

Enhanced crew safety. Unlike the Space Shuttle, the PLS would not have main propulsion engines or large payload bay. By removing large payload-carrying requirements from personnel delivery missions, the PLS would be a small, compact vehicle. It is then more feasible to design an abort capability to safely recover the crew during critical phases of the launch and return from orbit.

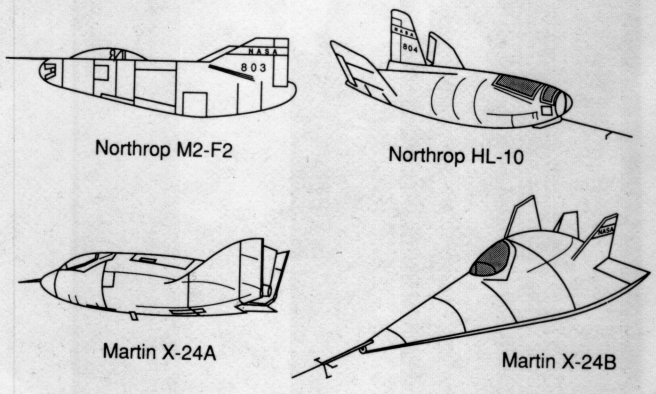
Affordable costs. As a small vehicle designed with available technologies, the PLS is forecasted to have a low development cost. Subsystem simplification and an aircraft approach to PLS ground and flight operations can also greatly lower the costs of operating PLS.

Candidate Shapes

Two designs being considered for PLS differ in their aerodynamic characteristics and mission capabilities. While a Johnson Space Center's approach uses a blunt cone shape with a parachute landing system, the Langley Research Center's design is a lifting body that can make a conventional runway landing on return from orbit.

History of Lifting-Body Research

Predating and influencing the design of the Space Shuttle, several lifting body craft including M2-F2, M2-F3, HL-10, X-24A, and X-24B were flown by test pilots during the period 1966-1975. The M2-F2 and the HL-10 were proposed in the 1960s to carry 12 people to a space station following launch on a Saturn 1B. The HL-20 PLS concept has evolved from these early shapes. The "HL" designation stands for horizontal lander, and "20" reflects Langley's long-term involvement with the lifting body concept, which included the Northrop HL-10.



U.S. lifting-body configurations (1960's - 1970's)

Advantages of Lifting Bodies

A lifting-body spacecraft, such as the HL-20, would have several advantages over other shapes. With higher lift characteristics

during flight through the atmosphere while returning from orbit, the spacecraft can reach more land area, and the number of available landing opportunities to specific sites would be increased. Loads during entry, in terms of g-forces, would be limited to about 1.5 g. This is important when returning sick, injured, or deconditioned Space Station crew members to Earth. Wheeled runway landings would be possible, permitting simple, precision recovery at many sites around the world, including the Kennedy Space Center launch site.

HL-20 PLS Missions

Delivery of passengers to Space Station Freedom would be the primary mission of a PLS. For the baseline space station mission, the crew size would be eight passengers (a space station crew) and two flight crew members.

Interior view of HL-20 lifting body

A typical PLS mission operation scenario, using a HL-20, would commence at the Kennedy Space Center with the HL-20 being processed horizontally in a vehicle processing facility while an expendable launch vehicle is processed vertically in a separate facility. The launch vehicle and HL-20 would be mated at the launch pad and the launch sequence initiated as the space station passes over the launch site.

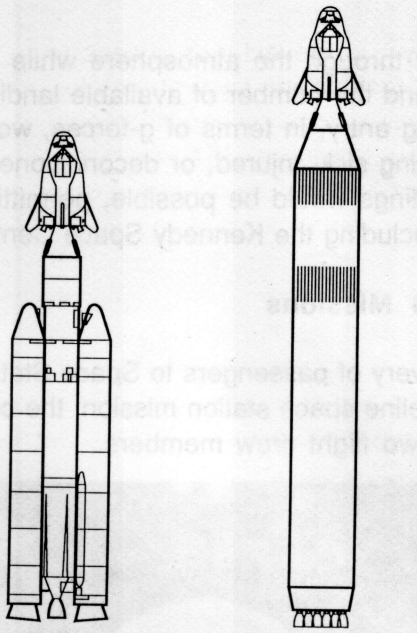
Following launch, the HL-20 would initially enter a low 100 nautical mile orbit to chase after the space station and then transfer up to the space station orbit altitude of 220 nautical miles. After rendezvous and docking at Space Station Freedom, crews would be exchanged, followed by a HL-20 return to Earth at the earliest opportunity.

The HL-20 would land horizontally on a runway in manner similar to the Space Shuttle. Total mission duration would not exceed 72 hours.

Other potential missions defined for a PLS include the orbital rescue of stranded astronauts, priority delivery and observation missions, and missions to perform satellite servicing. For these other missions, the basic HL-20 design would be unchanged, but interior subsystems and arrangements would be modified according to crew accommodations, duration, and equipment required for the particular mission.

HL-20 PLS Launch Vehicles

The HL-20 concept of the PLS is adaptable to several launch vehicle concepts. Titan III is an existing booster system which could be used for unmanned prototype launches or would require modification to be used as a manned system. A future launch system option is the National Launch System under study by the Air Force and NASA. Choice of a launch system for the HL-20 PLS would depend both on the required date of initial PLS operations and the cost of booster development and launches.

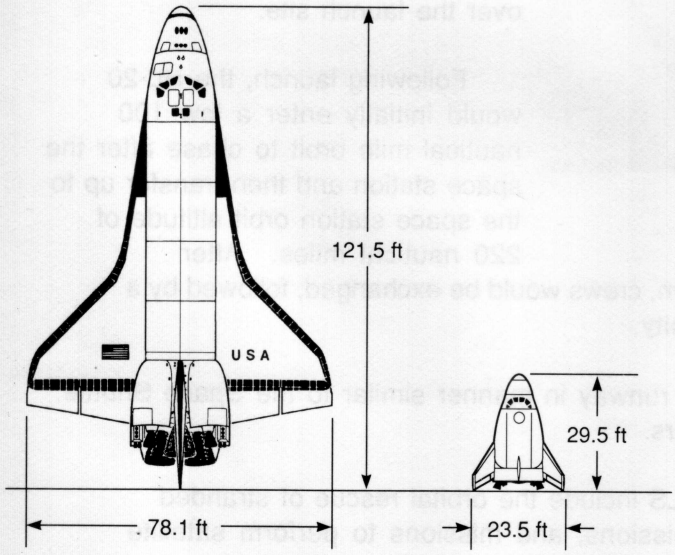


Titan III (Prototype) NLS Core Stage (Operational)

HL-20 PLS booster options

Design Features

The design philosophy of the HL-20 PLS concept has been to complement the Space Shuttle with safe, reliable manned transportation at the lowest cost. Of utmost importance is crew safety with emphasis being given in the HL-20 design to launch abort situations and the protection of the crew during vehicle recovery. Other requirements had focused on minimizing life-cycle costs of the system by insuring simple operations, low-cost manufacturing, and high utilization potential.

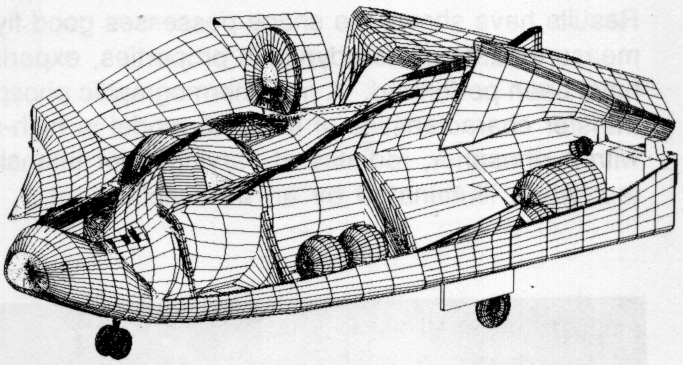


STS Orbiter Versus HL-20 Glider
(Courtesy Rockwell International Corp.)

With an overall length of about 29 feet and span across the wingtips of 23.5 feet, the HL-20 PLS concept would be a much smaller craft than the Space Shuttle Orbiter. In fact, the HL-20 could fit within the payload bay of the Shuttle with wings folded. Overall, the HL-20 would weigh 22,000 pounds without crew compared to the Space Shuttle Orbiter's empty weight of 185,000 pounds. The space available inside for crew and passengers, although less than Shuttle, would be more than found in today's small corporate business jets.

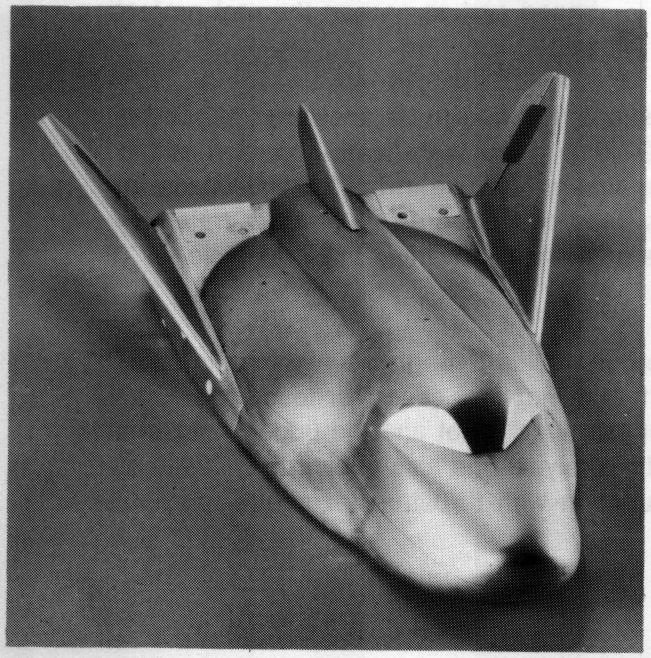
A very important aspect of the HL-20 PLS concept which would help insure low cost operations is its design for

maintainability. Large exterior access panels permit technicians easy access to subsystems which would be exposed and easily replaced if required. The vehicle would be processed in a horizontal position. Selection and design of subsystems would emphasize simplicity and reduce maintenance requirements. For example, hydraulic systems would be replaced by all-electric controls. Unlike the Space Shuttle, the HL-20 would not have a payload bay or main engine propulsion, thereby reducing the processing time. The thermal protection system would be similar to the Space Shuttle's, but the much smaller size of the HL-20 would result in major reductions in inspection and maintenance times. These design changes and subsystem simplifications, along with the adoption of aircraft maintenance philosophies, could reduce the HL-20 processing manhours to less than 10 percent of those currently used for the Space Shuttle Orbiter.



HL-20 PLS design for maintainability
(Courtesy Rockwell International Corp.)

The design of the HL-20 PLS concept has taken into account crew safety and survivability for various abort modes. The interior layout with a ladder and hatch arrangement has been designed to permit rapid egress of passengers and crew for emergencies on the launch pad. For on-the-pad emergencies or during launch where time is a critical element (launch vehicle fire or explosion), the HL-20 would be equipped with emergency escape rockets which can rapidly thrust the PLS away from the booster. The method is similar to that used during the Apollo program. Once at a safe distance, a cluster of three emergency parachutes would open to lower the vehicle to a safe ocean landing. Inflatable flotation devices ensure that it rides high in the water with at least one of two hatches available for crew emergency egress.



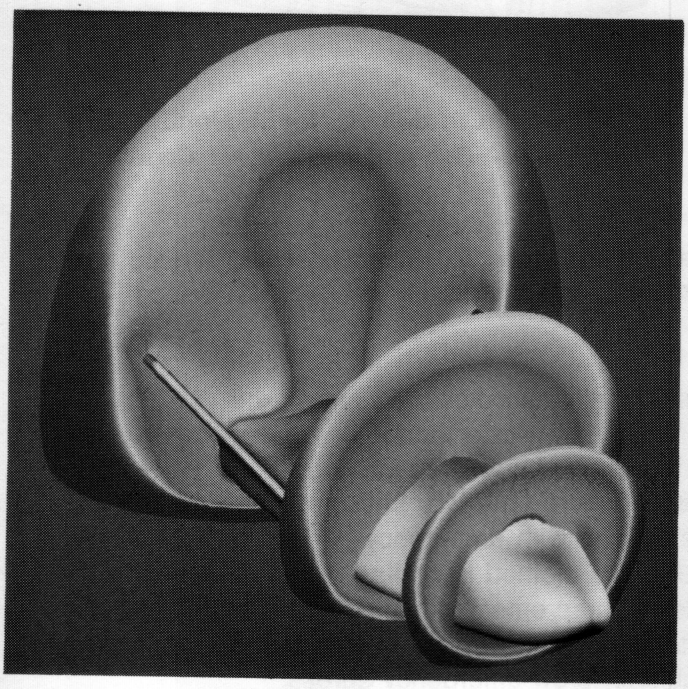
Transonic/Supersonic PLS model

HL-20 Lifting-Body Research

A significant amount of research effort has gone into experimental and computational investigations of the baseline HL-20 shape. The goal has been to amass a data base of information about this system to aid in management decisions for PLS development.

Experimental Aerodynamics. Using the extensive wind tunnel resources at Langley, researchers have compiled a comprehensive aerodynamic and aerothermodynamic data base on the HL-20 concept spanning the entire speed range the PLS would fly through. Several models were built for testing in the various tunnels ranging from a 5-foot

model used for force and moment tests at low speeds to 6-inch models used in hypersonic tests. Results have shown the shape possesses good flying qualities in all flight regimes. In addition to measurements of aerodynamic properties, experimental aerothermodynamic heating studies have been performed. A new thermographic phosphor technique has been used to study the heat transfer characteristics of a HL-20 model in high-speed wind tunnel tests. The model, coated with a phosphor, radiates at varying color intensities as a function of temperature during the test when illuminated by an ultra-violet light.



CFD flow field studies

Computational Fluid Dynamics (CFD). Computational fluid dynamics (CFD) codes, which mathematically simulate the flow field in the vicinity of the HL-20, were also used at Langley. These advanced computational grid techniques were used in conjunction with wind tunnel tests to study patterns of flow field phenomena, shock waves, stability and control and heating on the windward and leeward surfaces of the vehicle. Such computational analyses become critical in regimes where wind tunnels cannot duplicate the entry environment. For example, heating in the flight environment on this concept was predicted to be within the limits of Space Shuttle-based high-temperature, reusable surface insulation (HRSI) everywhere except at the nose of the vehicle, where Shuttle-based carbon-carbon thermal protection will be required.

Flight Simulation. Two of the major questions that had to be answered about the lifting-body concept were how to control the HL-20 during the high-heating portion of the reentry from orbit, and what is the proper guidance scheme for use in the landing phase to enhance its flying qualities. Langley researchers used a six-degree-of-freedom trajectory analysis technique along with mass, inertia and aerodynamic properties of the vehicle to investigate the entry phase of flight.

Results have shown that the concept can be controlled through the hypersonic entry using only 30 pounds of reaction control thruster fuel in nominal cases, or less than 200 pounds of fuel in cases where the vehicle center of gravity is offset and the upper atmosphere density and wind profiles are off-nominal. The entry analysis has also shown the effects of using the vehicle's aerodynamic surfaces in conjunction with thrusters for control purposes.

In addition to computer modeling of vehicle controllability during entry, a flight simulator has been set up at Langley to permit pilots to study the final landing phase of flight. Starting at an altitude of 15,000 feet, the simulation presents the pilot a realistic view of the approach to a runway landing. Using a side-stick controller, pilots, including one who flew the X-15 rocketplane and the lifting bodies, have demonstrated this configuration to be controllable and capable of pinpoint landings.

HL-20 PLS landing simulation

Contracted Efforts

In October 1989, Rockwell International (Space Systems Division) began a year-long contracted effort managed by Langley Research Center to perform an in-depth study of PLS design and operations with the HL-20 concept as a baseline for the study. Using a concurrent engineering approach, Rockwell has factored supportable, efficient design and operations measures into defining a detailed, cost-effective design along with a manufacturing plan and operations assessment. A key finding of this study is the realization that while design and technological factors can reduce costs of a new manned space transportation system, further significant savings are possible only if a new operations philosophy is adopted -- treating PLS in a manner similar to an operational airliner rather than a research and development space vehicle.

In October 1991, the Lockheed Advanced Development Company began a study to determine the feasibility of developing a prototype and operational system. The study objectives are to assess technical attributes, to determine flight qualification requirements, and to develop cost and schedule estimates.

HL-20 PLS Full-Scale Research Model

A cooperative agreement between NASA, North Carolina State University and North Carolina A&T University led to the construction of a full-scale model of the HL-20 PLS for further human factors research on this concept. Students at the universities, with requirements furnished by Langley and guidance from university instructors, designed the research model during their spring 1990 semester with construction following during the summer.

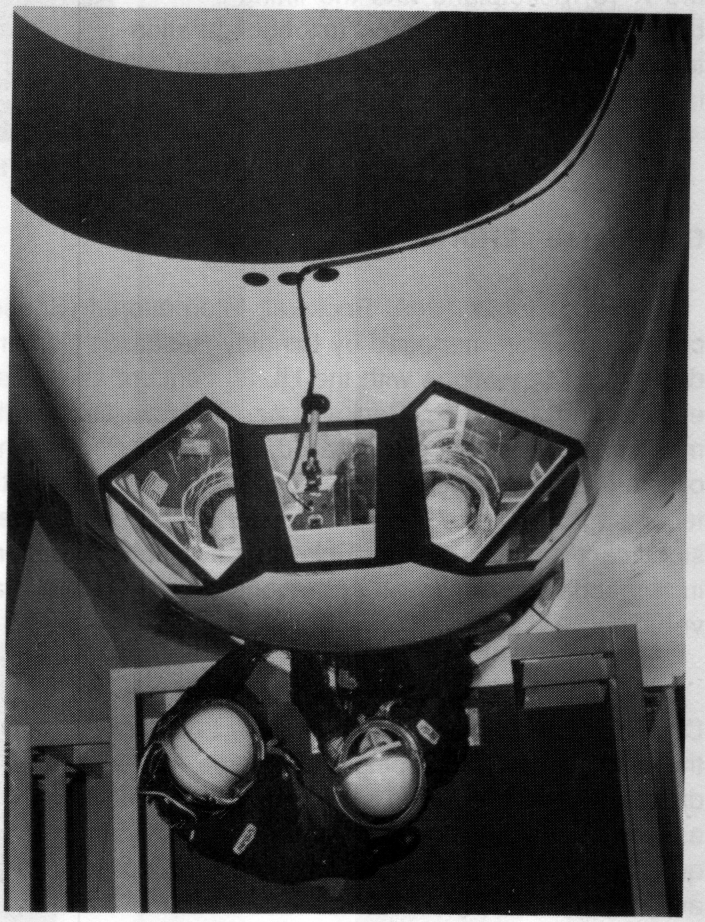
HL-20 model under construction
(Courtesy Joe Steffen, NCSU)

The human factors research objectives, using this model, were to assess crew ingress and egress operations, assess crew volume and habitability arrangements, and determine visibility requirements for the crew during critical docking and landing operations.

The testing, using Langley Research Center volunteers as subjects, was completed on the HL-20 model in December 1991. Langley volunteers, wearing non-pressurized flight suits and helmets, were put through a series of tests with the craft placed in both horizontal and vertical modes.

The horizontal study found, for example, that a 10-member crew has adequate volume to quickly and orderly get in and out of the spacecraft; the available volume and proximity to others is more than reasonably acceptable for a 10-member crew; more side-head room is desirable for the last row of seats to accommodate someone taller than 5 feet 7 inches; a wider aisle, removable seats and more training could improve emergency personnel capabilities and performance; more downward viewing capability for the pilot is desirable. Structural supports in the windows could also reduce viewing; and the cockpit display and seat design must be integrated with window placement.

Testing the HL-20 in a vertical position as oriented for launch posed a new set of factors. Getting in and out of the spacecraft, for example, required climbing through a hatch and up or down a ladder. In the horizontal mode, crew members walked along an aisle leading through the tail, which would be the exit-entry path at a space station or on the ground after a runway landing.



HL-20 testing in a vertical position as oriented for launch

Partial-pressure suits, borrowed from the Johnson Space Center in Houston, were used for part of the study. Participants noticed less head room and restricted movement with the bulkier and heavier suits.

The results of the human factors studies have shown where improvements in the baseline HL-20 design are desirable. These improvements will have little impact on overall vehicle shape or aerodynamic performance.

Summary

Langley Research Center has defined a lifting-body PLS for assured manned access to space for future U.S. space missions. This reusable vehicle, designated the HL-20, has been designed for safe and reliable operations; improved operability, maintainability and affordability; and reduced life-cycle costs associated with placing people in orbit.

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